# EYEGLASS LENS PROCESSING APPARATUS

## BACKGROUND OF THE INVENTION

The present invention relates to an eyeglass lens processing apparatus for processing the periphery of eyeglass lenses.

A known eyeglass lens processing apparatus is configured such that a lens to be processed is chucked (held) between two lens rotating shafts; the chucked lens is rotated by rotating the lens rotating shafts through use of a motor; and the lens is pressed against an abrasive wheel while the lens is being rotated, to thus process the periphery of the lens. When a lens is to be processed by such an apparatus, a cup which is a jig for retaining the lens is fixedly attached to the optical center or the frame center of the lens, and then the cups is attached to one of the lens rotating shafts, whereby the lens is chucked and is processed. The cup is fixedly attached to the lens through use of an adhesive tape or by suction.

However, if excessive load that is greater than the force required to retain the lens is exerted on the lens during the course of the lens being processed while being pressed against the abrasive wheel, rotational displacement or so-called axial displacement arises between the cup (i.e., the lens rotating shafts) and the lens. When such axial displacement arises, the axial angle precision of the processed lens is deteriorated,

along with reproducibility of a finished shape.

## SUMMARY OF THE INVENTION

The present invention has been conceived in view of the problems in the related art, and a technical challenge to be met by the invention is to provide an eyeglass lens processing apparatus which enables highly-precise processing of a lens while suppressing occurrence of axial displacement, which would otherwise arise during processing operation.

In order to solve the problem, the prevent invention is characterized by comprising the following configuration.

(1) An eyeglass lens processing apparatus for processing a periphery of an eyeglass lens comprising:

a lens rotation unit which includes lens rotating shafts which hold a lens to be processed and a first motor, and rotates the held lens by rotating the lens rotating shafts by first torque of the first motor;

a rotatable processing tool;

an inter-axis distance changing unit which includes a second motor, and changes an inter-axis distance between a rotational center axis of the lens rotating shafts and a rotational center axis of the processing tool by relatively moving the lens rotating shafts relative to the processing tool by second torque of the second motor;

a monitor unit which detects the first torque to be

transmitted to the lens rotating shafts; and

a control unit which controls driving of at least one of the first and second motors so as to adjust at least one of a rotational speed of the lens rotating shafts and processing pressure exerted on the lens, on the basis of a result of detection of the monitor unit, such that the first torque becomes lower than a predetermined allowable torque level which is determined so as not to cause rotational displacement between the lens rotating shafts and the lens.

(2) The eyeglass lens processing apparatus according to (1), further comprising:

a detection unit which detects a rotational angle of the lens rotating shafts,

wherein the control unit adjusts the processing pressure on the basis of the detected rotational angle by controlling driving of the second motor to change the inter-axis distance.

(3) The eyeglass lens processing apparatus according to (1), further comprising:

a detection unit which detects a rotational angle of the first motor,

wherein the monitor unit detects the first torque on the basis of a difference between a rotational angle of a rotation instruction signal issued to the first motor and the detected

rotational angle.

(4) The eyeglass lens processing apparatus according to (1), wherein the monitor unit detects the first torque by detecting an electric current flowing into the first motor.

(5). The eyeglass lens processing apparatus according to (4), wherein the control unit controls the electric current flowing into the first motor such that the detected electric current becomes lower than a limit value determined on the basis of the allowable torque level.

(6) An eyeglass lens processing apparatus for processing a periphery of an eyeglass lens, comprising:

a lens rotation unit which includes lens rotating shafts which hold a lens to be processed and a first motor, and rotates the held lens by rotating the lens rotating shafts by torque of the first motor;

a rotatable processing tool;

an inter-axis distance changing unit which includes a second motor, and changes an inter-axis distance between a rotational center axis of the lens rotating shafts and a rotational center axis of the processing tool by relatively moving the lens rotating shafts relative to the processing tool by torque of the second motor;

a detection unit which detects a rotational angle of the lens rotating shafts;

a detection unit which detects an electric current flowing into the first motor; and

a control unit which controls the electric current flowing into the first motor such that the detected electric current becomes lower than a predetermined limit value, and controls driving of the second motor on the basis of the detected rotational angle such that the inter-axis distance is changed.

(7) An eyeglass lens processing apparatus for processing a periphery of en eyeglass lens, comprising:

a lens rotation unit which includes lens rotating shafts which hold a lens to be processed and a first motor, and rotates the held lens by rotating the lens rotating shafts by torque of the first motor;

a rotatable processing tool;

an inter-axis distance changing unit which includes a second motor, and changes an inter-axis distance between a rotational center axis of the lens rotating shafts and a rotational center axis of the processing tool by relatively moving the lens rotating shafts relative to the processing tool by torque of the second motor;

a detection unit which detects a rotational angle of the first motor;

a detection unit which detects a difference between a rotational angle of a rotation instruction signal issued to the first motor and the detected rotational angle; and

a control unit which controls driving of at least one of the first and second motors on the basis of the detected difference so as to adjust at least one of a rotational speed of the lens rotating shafts and processing pressure exerted on the lens.

The present disclosure relates to the subject matter contained in Japanese patent application No. 2003-028588 (filed on February 5, 2003), which are expressly incorporated herein by reference in their entireties.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic outside view of an eyeglass lens processing apparatus according to the present invention;

Fig. 2 is a schematic structural diagram of a lens processing section;

Figs. 3A and 3B are schematic structural diagrams of a carriage section;

Fig. 4 is a view of the carriage section shown in Fig. 2 when viewed in a direction E;

Fig. 5 is a view showing chucking of a lens performed by two lens rotating shafts;

Fig. 6 is a schematic block diagram of a control system of the eyeglass lens processing apparatus; and

Fig. 7 is a view showing a relationship between a rotational angle difference $\Delta\theta$ and torque T of a lens rotating motor.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

An embodiment of the present invention will be described hereinbelow with reference to the drawings. Fig. 1 is a schematic outside view of an eyeglass lens processing apparatus according to the present invention. An eyeglass frame shape measurement device 2 is disposed in an upper right of a system main unit 1. An apparatus described in, e.g., US 5333412 (JP-A-4-93164) and US Re. 35898 (JP-A-5-212661) can be used as the measurement device 2. A switch panel section 410 having switches to be used for controlling the measurement device 2; a display 415 for displaying processing information and the like; and a switch panel section 420 having switches to be used for entering processing requirements, issuing a processing instruction and the like are arranged front of the measurement device 2. Reference numeral 402 designates a reclosable window for use with a processing chamber.

Fig. 2 is a schematic structural diagram of a lens processing section to be disposed inside a housing of the main unit 1. A carriage section 700 is mounted on a base 10. A lens

to be processed (hereinafter simply called a "lens") LE chucked (held) between two lens rotating shafts 702L, 702R of a carriage 701 is processed by a group of abrasive wheels 602 attached to an abrasive wheel rotating shaft 601. The group of abrasive wheels 602 includes a rough abrasive wheel 602a for a plastic lens; a rough abrasive wheel 602b for a glass lens; and a finishing abrasive wheel 602c for beveling processing and flat processing. The shaft 601 is rotatably attached to the base 10 by a spindle 603. A pulley 604 is attached to the right end of the shaft 601, and is coupled through a belt 605 to a pulley 607 attached to a rotating shaft of an abrasive wheel rotating motor 606. A lens shape measurement section 500 is disposed rearward of a carriage 701.

The configuration of the carriage section 700 will now be described with reference to Figs. 2 through 4. Figs. 3A and 3B are schematic structural diagrams of the carriage section 700. Fig. 4 is a view of the carriage section 700 shown in Fig. 2 when viewed in direction E.

The carriage 701 can cause the shafts 702L, 702R to chuck and rotate the lens LE. Further, the carriage 701 is rotatable and slidable with respect to a carriage shaft 703 fixed to the base 10 and extending parallel to the shaft 601. A lens chuck mechanism, a lens rotation mechanism, a X-axial direction

movement mechanism for moving the carriage 701, and a Y-axial direction movement mechanism for moving the carriage 701 will be described hereinafter under the definition that a direction in which the carriage 701 is moved parallel to the shaft 601 is taken as the X-axial direction, and a direction in which a distance between the rotational center axis of the shafts 702L, 702R and the rotational center axis of the shaft 601 is changed by rotation of the carriage 701 is taken as the Y-axial direction.

<Lens chuck mechanism, and lens rotation mechanism>

The shaft 702L and the shaft 702R are rotatably held coaxially by a left arm 701L and a right arm 701R of the carriage 701, respectively. A cup receiver 303 is attached to the right end of the shaft 702L. A lens presser (retainer) 304 is attached to the left end of the shaft 702R. A chucking motor 710 is fixed to an upper center surface of the right arm 701R, and a pulley 711 attached to a rotating shaft of the motor 710 is coupled through a belt 712 to a feed screw 713 rotatably held inside the right arm 701R. The rotation of the feed screw 713 by the motor 710 causes a feed nut 714 to move in the axial direction of the shaft 702R so that the shaft 702R coupled to the feed nut 714 is moved in the axial direction. As a result of the shaft 702R having been moved toward the shaft 701L, the lens LE is chucked between the shafts 702L, 702R. As shown

in Fig. 5, at the time of processing, a cup 50 serving as a fixing jib has previously been fixedly attached to a front refractive surface of the lens LE, and a base section of the cup 50 is fixedly attached to the cup receiver 303 provided on the shaft 702L. The cup 50 encompasses a cup of suction type and a cup to be attached by way of an adhesive tape.

A motor mount block 720 is attached to the left end portion of the left arm 701L. A gear 721 is attached to the left end of the shaft 702L passing through the block 720. A lens rotating motor 722 is fixed to the block 720. Rotation of the motor 722 is transmitted to the shaft 702L by way of the gear 721 and a gear 724. A servo motor is used for the motor 722, and an encoder 722a is provided for detecting a rotational angle of a rotating shaft of the motor 722.

A pulley 726 is mounted on the shaft 702L inside the left arm 701L. The pulley 726 is coupled through a timing belt 731a, to a pulley 703a attached to the left end of a rotating shaft 728 rotatably held rearward of the carriage 701. A pulley 703b attached to the right end of the shaft 728 is coupled through a timing belt 731b, to a pulley 733 mounted on the shaft 702R inside the carriage right arm 701R. The pulley 733 is slidable in the axial direction of the shaft 702R. By this configuration, the shaft 702L and the shaft 702R rotate synchronously.

<X-axial direction movement mechanism and Y-axis direction movement Mechanism of carriage>

A moving arm 740 is attached to the shaft 703 so as to be slidably movable along with the carriage 701 in the X-axial direction. A front portion of the arm 740 is made slidable over a guide shaft 741 fixed to the base 10 in parallel with the shaft 703. A rack 743 extending in parallel with the shaft 703 is attached rearward of the arm 740. A pinion 746 attached to a rotating shaft of an X-axial direction movement motor 745 meshes with the rack 743. The motor 745 is fixed to the base 10, and the carriage 701 is moved in the X-axial direction along with the arm 740 by rotational drive of the motor 745.

As shown in Fig. 3B, a swingable block 750 is attached to the arm 740 so as to be pivotable around an axis La coinciding with the rotational center axis of the shaft 601. A distance from the center axis of the shaft 703 to the axis La is set so as to be equal to a distance from the center axis of the shaft 703 to the rotational center axis of the shafts 702L, 702R. A Y-axial direction movement motor 751 is fixed to the swingable block 750. A servo motor is used for the motor 751, and an encoder 751a is provided for detecting a rotational angle of a the rotating shaft of the motor 751. Rotation of the motor 751 is transmitted, through a pulley 752 and a belt 753, to

a female thread 755 held in a rotatable manner by the block 750. A feed screw 756 is inserted into and meshed with a screw section provided in the female thread 755. The feed screw 756 is vertically moved by the rotation of the female thread 755.

The upper end of the feed screw 756 is fixed to the block 720. As a result of the feed screw 756 having been vertically moved by rotational drive of the motor 751, the block 720 is vertically moved along guides 758a, 758b, whereby the vertical position of the carriage 701 attached to the block 720 can also be changed. That, the carriage 701 is pivoted around the shaft 703 as the center of rotation, thereby changing a distance L between the rotational center axis of the shafts 702L, 702R and the rotational center axis of the shaft 601. A processing pressure to be exerted on the lens LE (the pressure for pressing the lens LE against the abrasive wheel 602) is adjusted by controlling the torque of the motor 751. The torque of the motor 751 is controlled by a voltage imparted to the motor 751. Incidentally, a compression spring, or the like, is preferably interposed between, for example, the left arm 701L and the arm 740 in order to lessen the downward load imposed on the carriage 701. The mechanism for adjusting the processing pressure can also be constituted by a spring for pulling the carriage 701 toward the abrasive wheel 601 and a mechanism for changing the force of the spring.

Next, operation of the eyeglass lens processing apparatus will be described with reference to a schematic block diagram of a control system shown in Fig. 6. After an outline shape of lens frames of the eyeglass frame for fitting the lens LE has been measured by the measurement device 2, when a data input switch of the panel section 420 is pressed, data on the obtained frame shape are stored in memory 120. The outline shape is graphically displayed on a display 415, and an operator inputs layout data pertaining to a wearer by operating switches of the panel section 420. After required input has been completed, the lens LE is chucked with the shafts 702L, 702R and processed.

When pressing a processing start switch of the panel section 420, a control section 100 obtains radius vector information ($r\delta n$, $r\theta n$) of the outline shape data where the chucking center of the lens LE is taken as a processing center, on the basis of the input layout data. $r\delta n$ designates a radius vector length, and $r\theta n$ designates a radius vector angle. Subsequently, the obtained radius vector information ($r\delta n$, $r\theta n$) ($n = 1, 2, 3, \ldots, N$) is substituted into the following equations, thereby determining the maximum value of L. R denotes the radius of the abrasive wheel 602, and L denotes a distance between the rotational center axis of the shafts 702L, 702R and the rotational center axis of the shaft 601.

Equation 1

$$L = r\delta n \bullet \cos r\theta n + \sqrt{R^2 - (r\delta n \bullet \sin r\theta n)^2} \quad (n = 1, 2, 3, \ldots, N)$$

Next, the radius vector information ($r\delta n$, $r\theta n$) is rotated around the processing center by each arbitrary minute unit angle, thereby determining a maximum L obtained at that time in the same manner as mentioned previously. Assuming that the rotational angle is taken as $\xi i$ ($i = 1, 2, \ldots, N$), the foregoing calculation is performed over the entire circumference of the lens LE, where the maximum L achieved at each $\xi i$ is taken as Li, and $r\theta n$ achieved at that time is taken as $\Theta i$. At that time, ($\xi i$, Li, $\Theta i$) ($i = 1, 2, \ldots, N$) are stored in the memory 102 as processing correction data associated with the inter-axis distance (axis-to-axis distance) L.

After the computation has been completed, the control section 100 activates the measurement section 500 on the basis of the processing correction data to measure the shapes of a front surface and a rear surface of the lens LE. Subsequently, the control section 100 obtains rough processing data and finishing data on the basis of the processing correction data in accordance with a predetermined program. When beveling processing is performed, bevel locus data are determined on the basis of the shape of the lens LE determined by the measurement

section 500. The bevel locus is determined by, e.g., a method for dividing an outer peripheral edge thickness of a lens with a certain ratio; a method for determining curve values from front and rear curves of a lens; a combination of these methods; or the like. Subsequently, the control section 100 sequentially performs rough processing and finishing operations by rotating the abrasive wheel 602 at high speed by controlling the drive of the motor 606.

When the lens LE is made of plastic, the control section 100 controls the drive of the motor 745 to move the carriage 701 in the X-axial direction such that the carriage 701 comes to a position above the rough abrasive wheel 602a. Next, in accordance with rough processing data, the lens LE is rotated by controlling the drive of the motor 722, and the carriage 701 is moved in the Y-axial direction by controlling the drive of the motor 751, whereby the lens LE is pressed against the rotating rough abrasive wheel 602a and thus rough-processed. The control section 100 controls the drive of the motors 722 and 751 through drivers 115 and 117 in accordance with ($\xi i$, $Li$) of the processing correction data ($\xi i$, $Li$, $\Theta i$). The rotational angle of the lens LE (shafts 702L, 702R) is detected by the encoder 722a. The inter-axis distance Li, which acts as the position to which the carriage 701 is moved in the Y-axial direction, is detected by the encoder 751a. Incidentally, the

processing correction data for rough processing data are determined while factoring in a region which is to be used for finishing.

When excessive load that is greater than the retaining force of the shafts 702L, 702R is imposed on the lens LE during the course of processing of the lens LE, a rotational displacement arises between the cup 50 (i.e., the shafts 702L, 702R) and the lens LE, thereby causing axial displacement. The driver 115 sends, to the servo motor 722 that rotates the shafts 702L, 702R, an instruction pulse signal for rotating the lens LE for each rotational angle $\xi i$. Concurrently, the rotational angle of the rotating shaft of the motor 722 is detected by the pulse signal output from the encoder 722a. The driver 115 compares the instruction pulse signal output to the motor 722 with the pulse signal output (issued) from the encoder 722a. If a difference exists therebetween, a voltage to be supplied to the motor 722 (i.e., an electric current flowing into the motor 722) is changed so as to eliminate the difference. By this feedback control operation, when load is exerted on the rotating shaft of the motor 722 as a result of processing (i.e., pressing of the lens against the abrasive wheel), the motor 722 increases torque T, thereby attempting to adjust the rotational angle of the rotating shaft of the motor 722 to the instructed position. As shown in Fig. 7, the torque T achieved

at this time is substantially proportional to a rotational angle error $\Delta\theta$ (a rotational angle error between the rotation instruction pulse signal output to the motor 722 and the pulse signal output from the encoder 722a). Therefore, the torque T of the motor 722 can be obtained from the rotational angle error $\Delta\theta$.

When the torque T has exceeded an allowable torque level T0 for retaining the lens LE without involvement of axial displacement, the control section 100 controls the drive of the motor 722, specifically lowers the torque of the motor 722 or stop rotational drive, thereby the rotational speed of the lens LE (the shafts 702L, 702R) is decreased. Alternatively, the control section 100 controls the drive of the motor 751, specifically lower the torque of the motor 751 or stop rotational drive, thereby decreasing the pressing pressure to be exerted on the lens LE. The torque of the motor 751 can be detected from an electric current flowing into the motor 751 detected by an electric current detection circuit of the driver 117. As in the case of the motor 722, the torque of the motor 751 can also be detected by detecting the rotation instruction pulse signal output to the motor 751 and the pulse signal output from the encoder 751a. The allowable torque level T0 is a value at which no rotational displacement arises between the cup 50 (i.e., the shafts 702L, 702R) and the lens LE. This level is

previously determined by a test or the like, and the determined value is stored in the memory 120.

When the torque T of the motor 722 falls (becomes) lower than a torque-up enable level T1 (which is also stored in the memory 120 beforehand) which is set lower than the allowable torque level T0, the control section 100 again controls the drive of the motors 722, 751 for performing normal processing operation. As mentioned above, when the torque T of the motor 722 exceeds the allowable torque level T0, the rotational speed of the lens LE, the processing pressure to be exerted on the lens LE, or the like is controlled such that the torque T falls lower than the allowable torque level T0, thereby decreasing the load exerted on the lens LE and preventing occurrence of axial displacement in the lens LE.

After rough processing operation has been completed, the control section 100 moves the carriage 701 in the X-axial direction of the X axis, to thereby move the lens LE to a position above the finishing abrasive wheel 602c. Subsequently, in accordance with the finishing data, rotation of the lens LE and movement of the carriage 701 in the X-and Y-axial directions are controlled, thereby performing finishing of the lens LE. If the torque T of the motor 722 exceeds the allowable torque level T0 during the course of finishing of the lens LE as well,

the control section 100 controls the drive of the motors 722, 751 such that the torque T falls lower than the allowable torque level T0.

In the above embodiment, information on the rotational angle difference $\Delta\theta$ between the rotation instruction pulse signal output to the motor 722 and the pulse signal output from the encoder 722a is used as a method for detecting (monitoring) the torque transmitted to the shafts 702L, 702R. However, as a matter of course, there may also be employed a method for providing torque sensors directly on the shafts 702L, 702R. The method for decreasing the processing pressure to be exerted on the lens LE such that the detected torque T falls lower than the allowable torque level T0 also encompasses a case where the lens LE is detached from the abrasive wheel 602.

Moreover, a configuration for setting a limit on an electric current flowing into the motor 722 for rotating the shafts 702L, 702R and controlling the drive of the motor 722 within the range of the limit value may also be employed as the method for preventing the torque T transmitted to the shafts 702L, 702R from exceeding the allowable torque level T0. The electric current flowing into the motor 722 is detected by the electric current detection circuit of the driver 115. The torque T of the motor 722; that is, the torque T transmitted to the shafts 702L, 702R is substantially proportional to the electric current flowing into the motor 722. Therefore, the

torque T of the motor 722 (i.e., the torque T transmitted to the shafts 702L, 702R) can also be detected (monitored) by means of detecting the electric current flowing into the motor 722. The limit imposed on the electric current flowing into the motor 722 is determined on the basis of the allowable torque level T0 at which no rotational displacement develop between the shafts 702L, 702R and the lens LE, and the limit value is to be stored in the memory 120.

Under any of the previously-described methods, the rotational angle of the lens LE is detected on the basis of the output from the encoder 722a, and the drive of the motor 751 is controlled on the basis of processing data ($\xi i$, $Li$) corresponding to the detected rotational angle, thereby controlling the inter-axis distance L.

Incidentally, although, in the embodiment, the lens (lens rotating shaft) is moved toward the abrasive wheel (abrasive wheel rotating shaft) for processing, the abrasive wheel (abrasive wheel rotating shaft) can be moved toward the lens (lens rotating shaft) for processing. In this case, a drive of a motor for moving the abrasive wheel (abrasive wheel rotating shaft) is controlled to adjust a pressing pressure. Further, although, in the embodiment, the abrasive wheel is used as a processing tool for the lens, known processing tools which can rotate to grind or saw (cut) the lens can be used instead of

the abrasive wheel.